Silicon-Germanium (SiGe) Technology
For Europa and Enceladus Lander or Probe Missions

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A Europa mission has been designated by the Decadal Study as the highest priority flagship mission for the next decade, and the Europa Geophysical Explorer (EGE), is likely to be the next large mission to the outer planets after Cassini. A Europa mission would likely include landers and/or surface probes.

Enceladus has recently captured the headlines after NASA's Cassini spacecraft returned images showing icy jets and towering plumes that might be erupting from near-surface pockets of liquid water.

Europa has extreme environmental conditions, with a surface temperature varying from a low of 50 Kelvin, up to 125 Kelvin, with a mean temperature of around 100 Kelvin. The surface of Enceladus is dominated by ice blocks at temperatures of 74 Kelvin to 80 Kelvin, with hot spots topping 100 Kelvin. Europa also has a high radiation environment: 20 Mrad per month at the surface. The Ice provides effective radiation shielding; the radiation dose at 10 cm depth into the ice is ~5 Krad per month.

These are harsh and challenging environments for electronics circuitry. SiGe technology is particularly suited to answer these demands. The performance characteristics of SiGe devices vary gracefully over this extreme temperature range, with no evidence of abrupt "killer" phenomena. The structure of SiGe devices also confers a "free perk" - multi-Mrad total dose hardness, with no intentional hardening.

Boeing is part of a NASA funded team, led by Dr. Cressler from Georgia Institute of Technology, which is developing SiGe Integrated Electronics for Extreme Environments. This university-NASA-industry team includes Georgia Institute of Technology, Jet Propulsion Laboratory, Auburn University, the University of Tennessee, Vanderbilt University, the University of Maryland, BAE Systems, IBM, and Lynguent Inc. The team focuses on versatile mixed-signal circuits, applicable to distributed interface, data acquisition, and control interfaces, which operate over a very wide range of temperatures: down to 43 Kelvin (-230 degC) without "warm boxes", and up to 398 Kelvin (+125 degC) in normal operation. Parallel spinoffs of this activity include the development of Si-Ge micro-controller and FPGA for these harsh environments.

In this paper we show the predicted (modeled) electron and proton flux environments encountered by a spacecraft at various orbital inclinations, and on the surface of Europa and Enceladus, in comparison to the Lunar environment. We then present the SiGe technology for Extreme Environments, and the design considerations for a SiGe electronic module in a lander or a probe on Enceladus, or in the harsh environment of Europa.